September 2010

NASA Electronic Parts and Packaging Program

Operation of a Giant Magnetoresistive (GMR) Digital Isolator, Type IL510, Under Extreme Temperatures

Richard Patterson, NASA Glenn Research Center
Ahmad Hammoud, ASRC Corp., NASA GRC
Scott Panko, ASRC Corp., NASA GRC

Background

Some applications in electrical power management, motor control, and data processing require signal isolation for proper operation, safety, noise elimination, and optimization, to name a few. Examples include switching of power transistors, isolated power interfaces, A/D converters, and data acquisition and transmission. A relatively new type of signal isolation, which is based on Giant Magnetoresistive (GMR) technology, could offer potential replacement for traditional means used for isolation such as optocouplers or inductive and capacitive coupling. These GMR isolators, which work on the principle of large variation in the electrical resistance of ferromagnetic and non magnetic thin-film materials with applied magnetic fields, produce rather large output signal resulting in improved sensitivity and higher accuracy. In addition, this technology is compatible with semiconductor integrated circuit manufacturing and, thus, it can be easily incorporated into system-on-chip packages [1].

The effects of extreme temperature exposure on the performance of a commercial-off-the-shelf (COTS) GMR digital isolator were evaluated in this work. The single channel, 2Mbps IL510-Series isolator features optional external synchronization clock and output enable, and utilizes a patented IsoLoop spintronic Giant Magnetoresistive technology introduced by NVE Corporation [2]. Some of the specifications of the isolator chip are listed in Table I.

Table I. Manufacturer specifications of NVE IL510 isolator.

Parameter	Symbol	IL510-3
Supply Voltage (V)	V_{DD}	3.0 to 5.5
Quiescent Current (µA)	I_{DD}	24 to 40
Output Current Drive (mA)	I_o	10
Recommended Operating Temperature (°C)	T_{oper}	-40 to +85
Maximum Operating Temperature* (°C)	T_{oper}, max	-55 to +150
Output Rise Time (ns)	t_r	1 to 3
Output Fall Time (ns)	t_f	1 to 3
Propagation Delay Time (ns)	t_{PLH}	25
Propagation Delay Time (ns)	t_{PHL}	25
Package		8-pin SOIC
Lot Number		081985

* Device will not be damaged but performance is not guaranteed.

The device was evaluated in terms of output response, output rise (t_r) and fall times (t_f), and propagation delays (using a 50% level between input and output during low to high (t_{PLH}) and high to low (t_{PHL}) transitions). The supply current of the gate circuit was also obtained. These parameters were recorded at various test temperatures between -190°C and +120°C. In addition, the effects of thermal cycling on the performance of the chip were determined by exposing it to a total of 12 cycles over the test temperature range. Following the cycling activity, measurements were performed again at the test temperatures of -190°C, +23°C, and +120°C. Finally, restart operation capability of the isolator chip under extreme temperatures was investigated by first soaking the device for a period of 20 minutes at either extreme of -190 °C or +120 °C with power off, followed then by applying power to the device and recording its characteristics.

Results and Discussion

Temperature Effects

Waveforms of the input and the output signal for the IL510 isolator at room temperature are shown in Figure 1. These waveforms were also obtained for all other test temperatures in the range from -190 °C to +120 °C. The isolator circuit was found to operate properly without any major changes in its characteristics throughout the entire test temperature range. Therefore, only those waveforms recorded at the extreme temperatures of -190 °C and +120 °C are presented here and are shown in Figures 2 and 3, respectively.

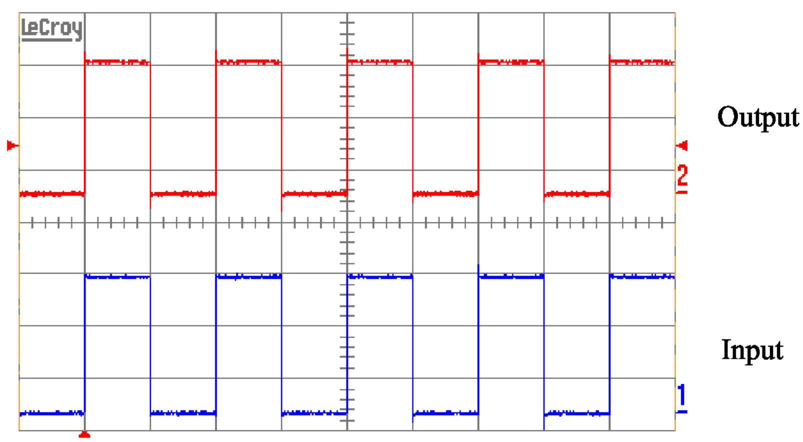

Figure 1. Input and output signal waveforms of IL510 isolator at +23 °C.

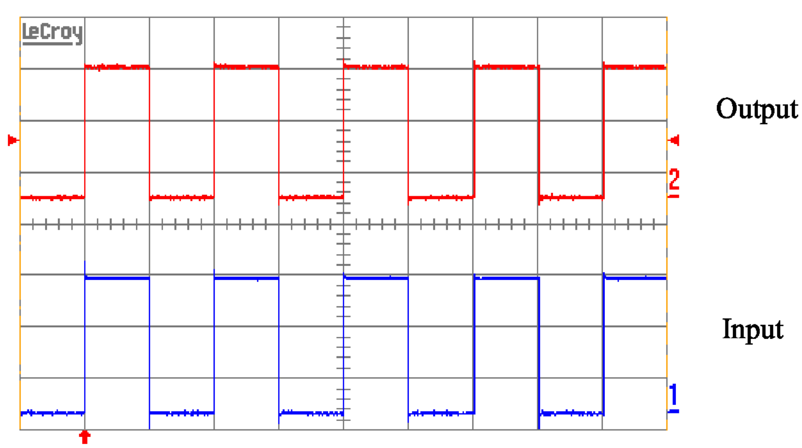

Figure 2. Input and output signal waveforms of IL510 isolator at -190 °C.

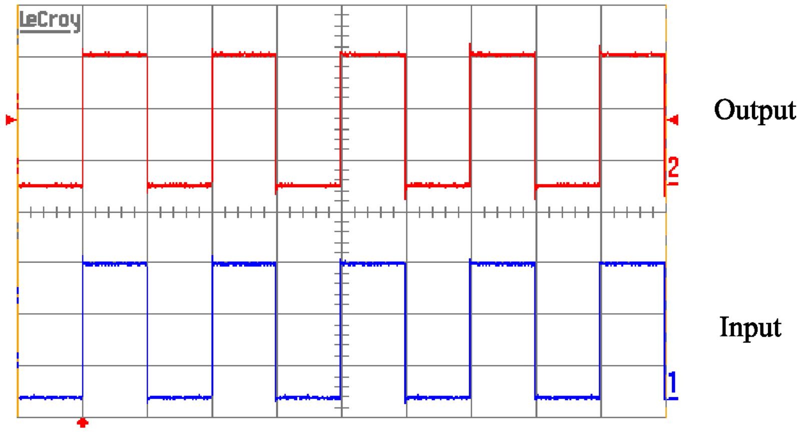

Figure 3. Input and output signal waveforms of IL510 isolator at +120 °C.

In addition to output signal stability, the GMR-based isolator did not experience any noticeable change in its output's duty cycle over the entire test temperature, as illustrated in Figure 4.

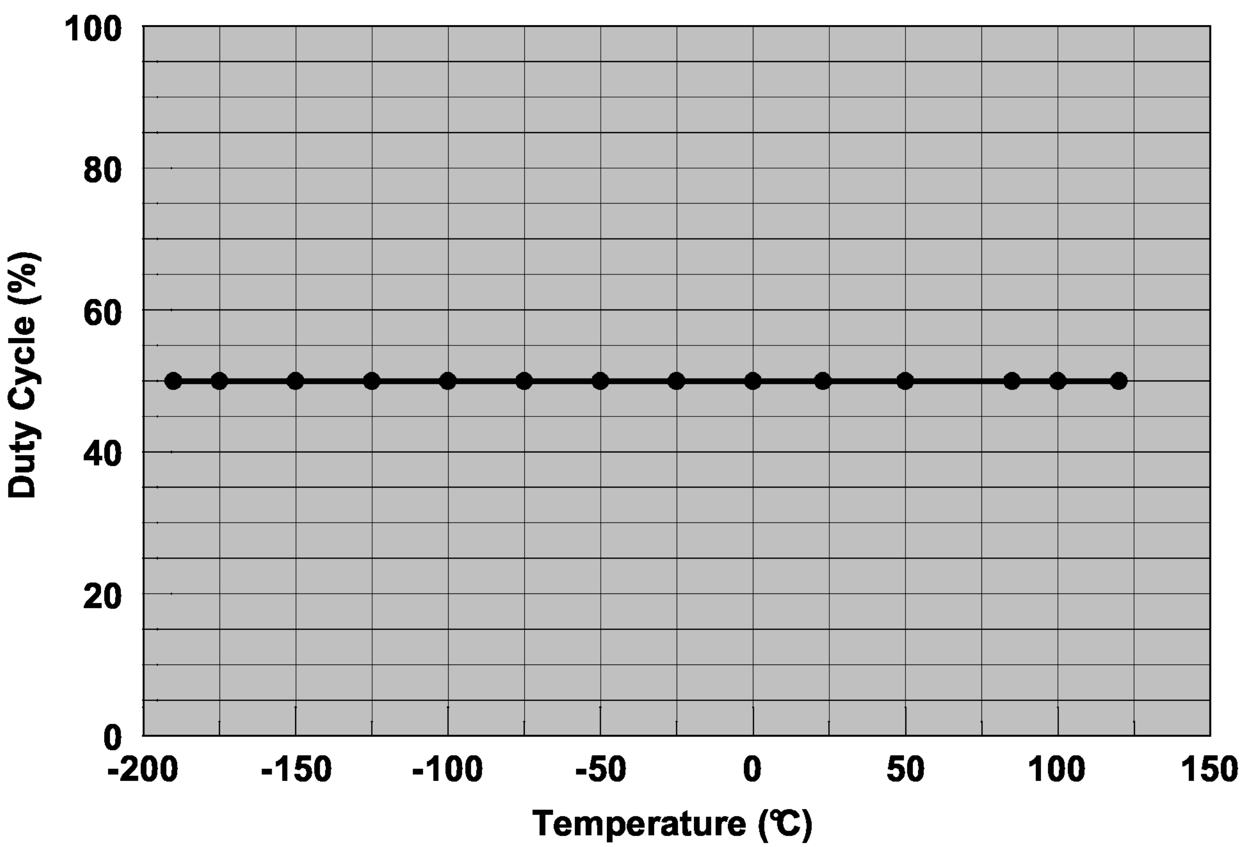

Figure 4. Duty cycle of the output signal of IL510 oscillator versus temperature.

The rise and fall times of the output signal of the isolator were also investigated in this evaluation. Figure 5 shows the variation in these properties as a function of temperature. The trend in the rise and the fall times was very similar as both properties exhibited gradual, but very minimal, increase with increasing test temperature, as shown in Figure 5.

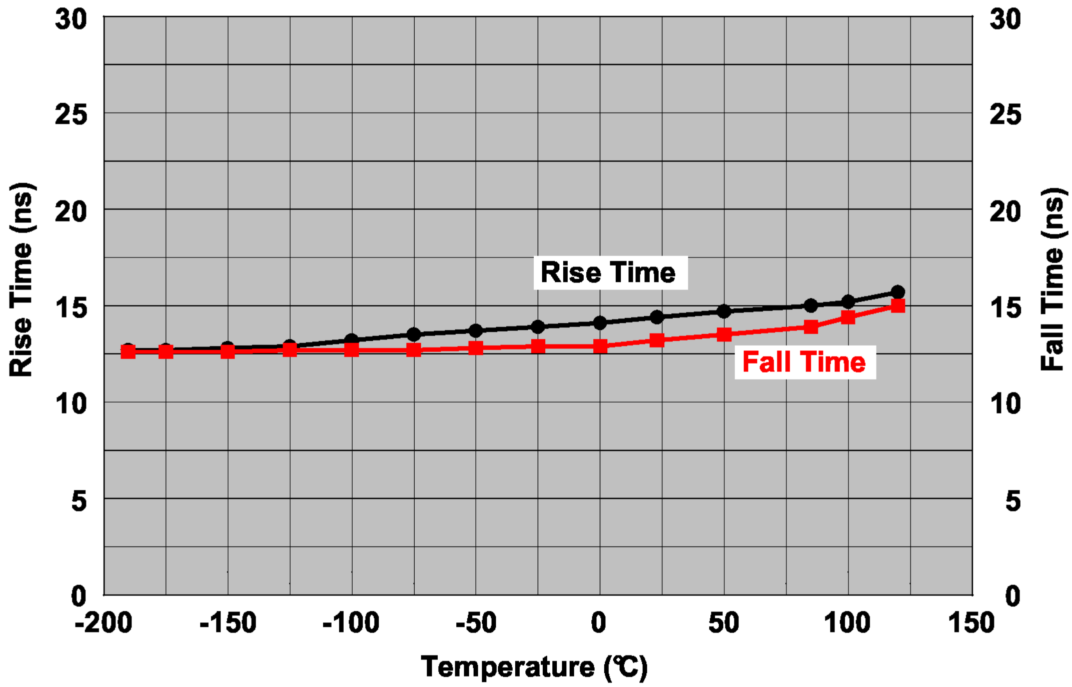

Figure 5. Rise and fall times of output signal of IL510 oscillator.

The other timing parameters evaluated for the IL510 isolator were the propagation delay times at 50% level between input and output signals. These delays were measured for both the low-to-high (t_{PLH}) and high-to-low (t_{PHL}) transitions and are depicted in Figure 6. Both of these properties experienced a slight gradual increase as temperature increased, and at any given test temperature, t_{PHL} has had a slight higher value than t_{PLH}, as shown in Figure 6.

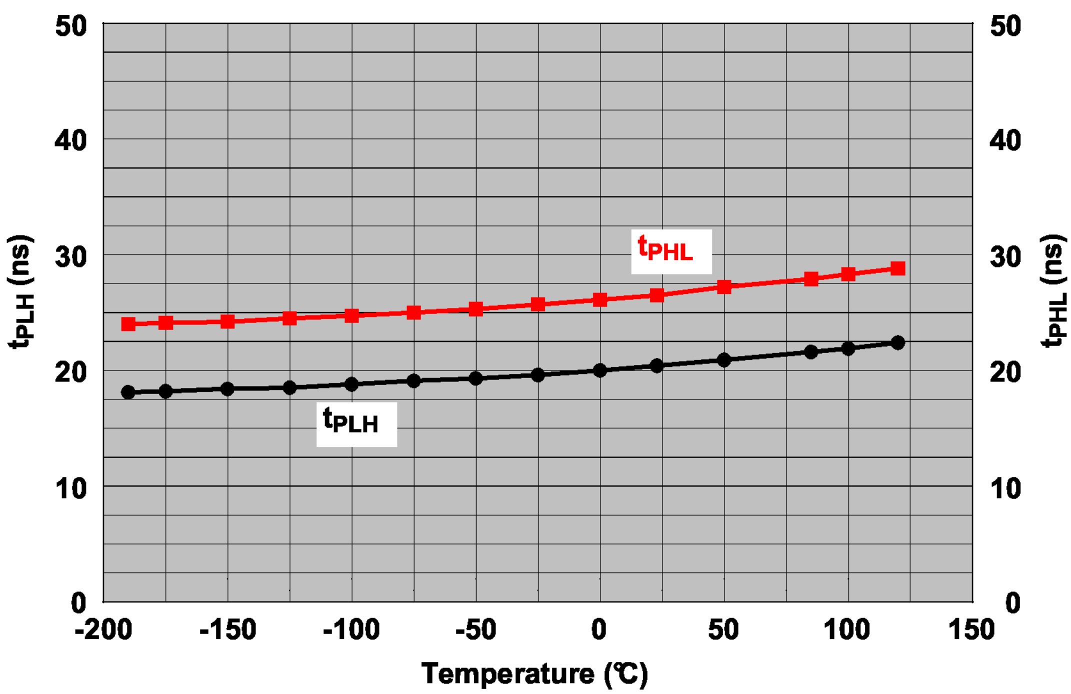

Figure 6. Propagation delay times versus temperature for the IL510 oscillator.

Variation in the supply current of the isolator circuit is shown in Figure 7. It can be seen that the supply current drops, almost in a linearly fashion, as temperature is increased from -190 °C to 120 °C. The drop in current at high temperature is beneficial as this translates into low power consumption by the device as well as limited internal heating.

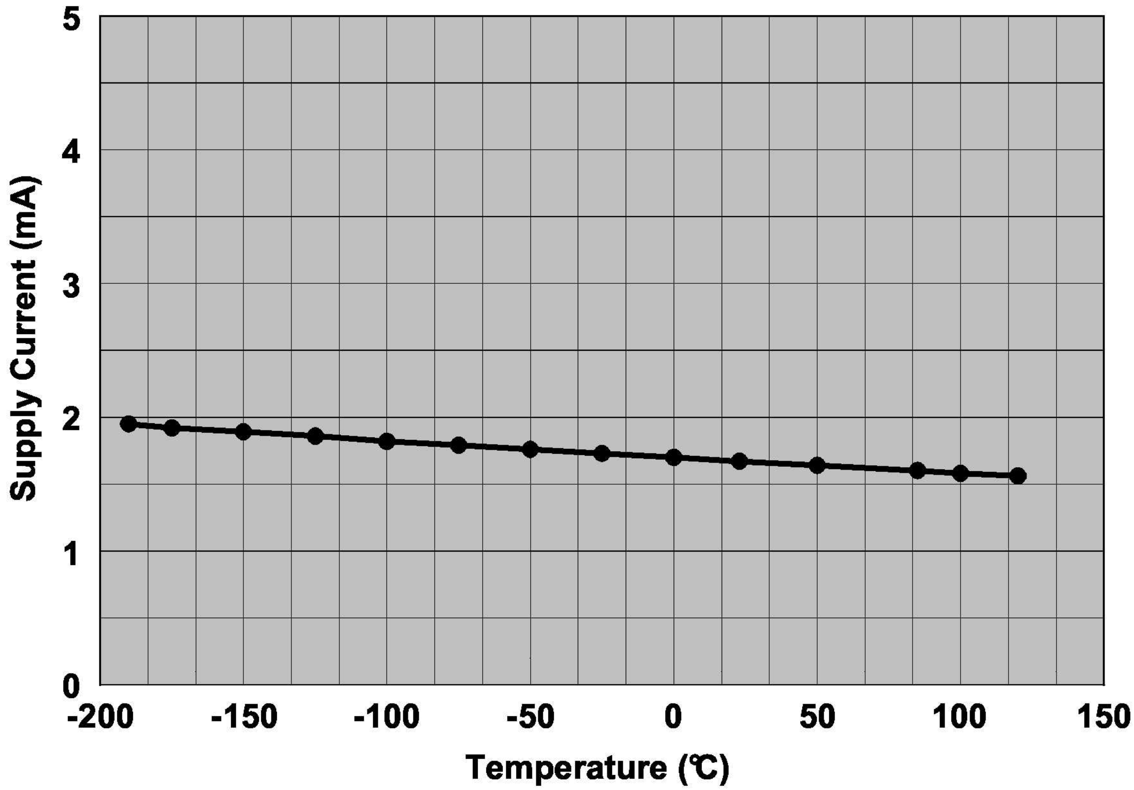

Figure 7. Supply current as a function of temperature for the IL510 isolator.

Effects of Thermal Cycling

The effects of thermal cycling on the operation of the IL510 isolator were determined by exposing the chip to a total of 12 cycles between -190 °C and +120 °C at a rate of 10 °C/min. The circuit was powered while the cycling activity was taking place. In addition to the pre-cycling data, readings of the investigated properties were taken during as well as after the cycling. No major change was observed in the characteristic behavior of the circuit due to cycling. Table II shows the pre- and post-cycling values of the investigated properties at the selected temperatures of -190 °C, 23 °C, and 120 °C. The limited cycling seemed to also have no effect on the packaging of the chip as no physical damage was observed.

Table II. Pre- and post-cycling data at selected temperatures.

T (°C)	I_s (mA)		t_r (ns)		t_f (ns)		τ_{PLH} (ns)		τ_{PHL} (ns)	
	Prior	Post	Prior	Post	Prior	Post	Prior	Post	Prior	Post
-190	1.95	1.95	12.7	12.9	12.6	12.6	18.1	17.7	24.0	24.9
+23	1.67	1.67	14.4	14.4	13.2	13.4	20.4	20.1	26.5	27.4
+120	1.56	1.56	15.7	15.5	15.0	14.4	22.4	22.5	28.8	29.1

Restart at Extreme Temperatures

Restart capability of the isolator chip at extreme temperatures was investigated by allowing it to soak for at least 20 minutes at each of the test temperatures of -190 °C and +120 °C without electrical bias. Power was then applied to the isolator, and measurements were taken on its output characteristics. The circuit was able to successfully restart at both extreme temperatures and the results obtained were the same as those attained earlier for both temperatures.

Conclusion

A relatively new type of signal isolation based on Giant Magnetoresistive (GMR) technology was investigated for potential use in harsh temperature environments. Operational characteristics of the 2Mbps single channel, IL510-Series commercial-off-the-shelf (COTS) digital isolator chip was obtained under extreme temperature exposure and thermal cycling in the range of -190 °C to +120 °C. The isolator was evaluated in terms of its output signal delivery and stability, output rise (t_r) and fall times (t_f), and propagation delays at 50% level between input and output during low to high (t_{PLH}) and high to low (t_{PHL}) transitions. The device performed very well throughout the entire test temperature range as no significant changes occurred either in its function or in its output signal timing characteristics. The limited thermal cycling, which comprised of 12 cycles between -190 °C and +120 °C, also had no influence on its performance. In addition, the device packaging underwent no structural damage due to the extreme temperature exposure. These preliminary results indicate that this semiconductor chip has the potential for use in a temperature range that extends beyond its specified regime. Additional and more comprehensive testing, however, is required to establish its operation and reliability and to determine its suitability for long-term use in space exploration missions.

References

[1]. NVE Corporation "GMR in Isolation," Application Bulletin AB-7, ISB-AP-007; Rev. March 2008. http://www.Isoloop.com

[2]. NVE Corporation "2 Mbps DC-Correct Digital Isolators," Data Sheet, Rev. E, ISB-DS-001-IL500-E, January 2009. http://www.nve.com

Acknowledgements

This work was performed at the NASA Glenn Research Center under GESS-2 Contract # NNC06BA07B. Funding was provided from the NASA Electronic Parts and Packaging (NEPP) Program Task "Reliability of SiGe, SOI, and Advanced Mixed Signal Devices for Cryogenic Power Electronics".